X66-80700

DE[redacted]SIFIED

Copy
RM S57E13

NACA RM S57E13

NACA

RESEARCH MEMORANDUM

for

The Office of the Assistant Secretary of Defense,

Research and Engineering

Department of Defense

RELATION OF CURRENTLY ESTIMATED ANP PERFORMANCE TO REQUIRED ANP PERFORMANCE

By Addison M. Rothrock and Richard S. Cesaro

[redacted]

Classification ... No. ...
Dated ** 4/21/65

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON

May 16, 1957

[redacted]

[redacted]

NACA RM S57E13

[redacted] THIS DOCUMENT CONSISTS OF...23......PAGES
NO.......OF 251....COPIES, SERIES......A..........

4583

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

for

The Office of the Assistant Secretary of Defense,
Research and Engineering
Department of Defense

RELATION OF CURRENTLY ESTIMATED ANP PERFORMANCE TO REQUIRED ANP PERFORMANCE

By Addison M. Rothrock and Richard S. Cesaro

INTRODUCTION

Over a period of several years, the Department of Defense and the Atomic Energy Commission have contracted for extensive studies leading to performance estimates of aircraft nuclear propulsion (ANP) systems. These studies have been supported by experimental research and by hardware development. Work in the propulsion area has centered in the Atomic Products Division of the General Electric Company and in the Pratt and Whitney Aircraft Division of United Aircraft Corporation. The Convair Division of General Dynamics Corporation and the Georgia Division of Lockheed Aircraft Corporation have made extensive aircraft performance studies using these nuclear propulsion systems. Less extensive analyses have been made by Douglas Aircraft Company and the Glenn L. Martin Company.

In evaluating the current status of the ANP program, it is necessary to determine the manner in which the estimated nuclear propulsion system performance in conjunction with the estimated airframe performance will lead to a useful military airplane. The purpose of this report is to present such information in a convenient summary form. This summary was prepared at the request of the Ad Hoc Group on Aircraft Nuclear Propulsion, Technical Advisory Panels on Aeronautics and Atomic Energy, Office of the Assistant Secretary of Defense, Research and Engineering.

The basis for comparison is that of powerplant specific weight. The approach is one of determining the maximum powerplant specific weight allowable to accomplish any of several different military missions and of then comparing this allowable specific weight with that believed by the engine manufacturers involved in the ANP program to be attainable within the present technology.

[redacted]

For the determination of the allowable powerplant, specific weights information is required on the weights of various major items comprising the operational airplane, such as airframe, payload, powerplant, and fuel, and on lift-drag ratios achievable. Estimates have been made of these quantities based on what is believed to be the most reliable information available, namely the data generated in the ANP program, the USAF Weapon System 110 program (long-range, supersonic strategic bomber), and the USAF and Navy programs concerned with the logistic carrier, aircraft early warning (AEW), and antisubmarine warefare (ASW) systems. 4583

Data on the attainable specific weights for the nuclear powerplants are the direct estimates of the engine manufacturers involved with the ANP program. Since the manufacturers whose data are used herein are continually refining their estimates, the estimates presented are continually changing; however, these refinements have not affected the general results presented. The feasibility of achieving the estimates will not be discussed. The extent to which other means of propulsion can provide the same airplane performance will not be discussed.

ANALYSIS

The method of analysis consists of generalizing the airframe performance that can currently be obtained for aircraft designed for various types of military missions (uses) and then determining the extent to which the estimated ANP systems are suitable for these aircraft. The airplane performance considered is based on an estimated weight breakdown and an estimated lift-drag ratio for the operational flight altitudes and speeds required for the different missions, with only passing reference to landing and takeoff requirements. This rather limited view of performance is reasonably satisfactory for defining the general areas of utility of an ANP system.

In determining propulsion system applicability, there are four factors that are paramount. These are:

(1) Fuel heat of combustion

(2) Propulsion efficiency

(3) Specific thrust, that is, thrust per pound of air per second

(4) Specific powerplant weight, that is, weight of powerplant per pound of thrust

With ANP the fuel heat of combustion is sufficiently high so that it need not be considered. The over-all engine system efficiency denotes the percentage of the reactor power output that is utilized in propelling the airplane and consequently is a factor in determining the size of the required reactor. The specific thrust determines the size of the turbomachinery required to produce the required thrust. These two factors, efficiency and specific thrust, play a major part in determining the specific powerplant weight. They are discussed in more detail in the appendi:

Estimated Permissible Powerplant Specific Weights for Several Types of Aircraft

The specific powerplant weight (propulsion system exclusive of chemical fuel) is equal to the ratio of the weight of the powerplant to the thrust produced. In an airplane in horizontal flight the thrust produced must equal that required. Hence, the specific powerplant weight must not exceed the ratio of powerplant weight, W_e, to the required thrust, F_r, which, by introducing the gross weight, W_g, of the airplane, may be written as the product of the ratio of the airplane gross weight to required thrust, W_g/F_r, times the ratio of powerplant weight to gross weight, W_e/W_g. Thus, to determine the applicability of ANP propulsion systems to given aircraft, we need to know the permissible specific powerplant weights for those aircraft and the estimated specific weights of ANP systems. The first step is to estimate the fraction of the total gross airplane weight assignable to the powerplant. Considering airplanes of 300,000 to 600,000 pounds gross weight, an examination of the data generated in the ANP, USAF-WS-110, and logistic carrier programs indicates the approximate weight distribution as shown in table I. It is noted that the value of airframe to gross weight ratio, W_{af}/W_g, for the nuclear powered airplanes is in each case greater than the value of corresponding chemically powered airplane. This is largely due to the concentration of weight for the crew and reactor shielding. The logistic carrier has a higher value for the ratio of airframe to gross weight, W_{af}/W_g, than does the combat airplane. This increase results from the lower payload density which dictates a larger fuselage than would otherwise be necessary, and higher payload to gross weight ratio. In practice, the weight distributions will vary from the figures given, but not sufficiently to affect the results reported herein.

A word of explanation is in order with respect to fuel weight, W_f. It will be noted that significant fuel weights are assigned to the nuclear powered airplanes. This results from the fact that the current thinking is that for safety and other reasons, the nuclear reactor will have to be shut down for takeoff and landing, and consequently, enough chemical fuel will have to be carried to accomplish these operations. An assumption to this effect is made throughout the present report.

Next, the ratio of the airplane gross weight to the thrust required is estimated. With the airplane in unaccelerated level flight the aerodynamic lift produced by the airplane must equal the airplane gross weight, and the thrust produced by the propulsion system must equal the aerodynamic drag. That is, the ratio of the airplane gross weight to thrust required equals the airplane lift-drag ratio (L/D). The lift-drag ratio is primarily a function of the airplane configuration and of the airplane velocity and altitude. In choosing representative values of L/D for the different airplane types, airplane speeds and altitudes must be assumed. Again, although there will be deviations from the values used, it is believed that the deviations will not affect the general discussion presented. From a consideration of the data presented in the airframe manufacturers' studies of ANP and WS-110, the values shown in table II have been chosen.

For the chemically fueled or nuclear fueled SAC bomber, an all-supersonic high-altitude or all-subsonic low-altitude (on-the-deck) mission is considered. 4583 The altitude for the on-the-deck mission is indicated here and subsequently as sea level (S.L.). The most recent WS-110 studies emphasize the all-supersonic high-altitude mission. For the combat airplanes two values of L/D are given for each altitude - Mach number condition. These represent the range of L/D's to be considered. The lift-drag ratios for the all-supersonic mission are noticeably higher than those considered attainable 18 months to two years ago, and may be unduly optimistic. However, these higher values which are currently quoted in the WS-110 studies have been used to guide the present study. The lift-drag ratios of the nuclear combat airplanes are lower than the values given for the corresponding chemically fueled airplanes to compensate for a possibly less efficient powerplant installation and, in the case of the supersonic bomber, for possible higher wing loadings. The supersonic Mach number and corresponding altitude of the nuclear fueled airplane are less than those for the chemically fueled airplane to partially compensate for the lack of a nuclear fueled afterburner. For comparison, data are given for the so-called split mission SAC bomber, (Weapon System 125A), which involves a long-range cruise at subsonic speeds on nuclear power followed by a short-range supersonic dash in the vicinity of the target, with thrust augmented by chemical afterburning.

From the percentage of gross weight assigned to the propulsion system and the lift-drag ratio values (table III), the corresponding values of permissible specific powerplant weight are computed. In the computations it is assumed that, for the nuclear powerplant, the installed powerplant weight is 0.05 W_g greater than the weight as specified by the powerplant manufacturer, to allow for items involved in the installation but not included in the manufacturer's specified weight.

$$\frac{W_{eng}}{F} = \left(\frac{W_e}{W_g} - 0.05\right)\frac{L}{D}$$

in which

W_e installed engine weight

W_{eng} powerplant weight as specified by the manufacturer

W_g airplane gross weight at flight condition

F thrust produced at Mach number and altitude under consideration

L/D airplane lift-drag ratio at Mach number and altitude under consideration

For the chemical powerplant the installation weight is assumed to be 20 percent of the installed powerplant weight.

4583 Since the data are on a thrust basis, they are equally applicable to the nuclear turbojet or the nuclear-powered turboprop. The turboprop is being, and should be, considered for the subsonic uses. In the present analysis, because of time limitations, turboprop data are not presented, although reference will be made to them. The permissible powerplant specific weights for the nuclear cruise - chemical dash mission are given in table III for purposes of comparison. The performance of this type system has been adequately covered in other presentations and will not be considered further in subsequent discussion.

The values in table III for the all nuclear-powered airplanes are summarized in figure 1. In each case, the depth of the band indicates the uncertainty in the estimates.

Having estimated the maximum permissible powerplant weight, the next step is to present the specific weights estimated by the powerplant manufacturers.

Estimated Powerplant Specific Weights Attainable

The General Electric air-cooled reactor system (air cycle) will be discussed first. Then the Pratt and Whitney liquid cooled reactor system (liquid cycle) will be discussed. It is assumed that the reader is reasonably familiar with these two systems.

Air cycle. - Table IV shows the estimated weight breakdown presented by General Electric for the air cooled reactor ANP system.

Using the total weight figure and the manufacturers' estimated thrust output data for the powerplant, the attainable powerplant specific weights presented in figures 2 and 3 for the specified turbine inlet gas temperatures of 2000° and 1800° F respectively are obtained. The data from figure 1 on the maximum permissible specific powerplant weights are included. The data for the 2000° F turbine inlet temperature (fig. 2) will be considered first. For the AEW or ASW airplane, the specific powerplant weight is satisfactory at 25,000 feet. For the logistic carrier, the specific weights shown do not include the shielding weight required for passenger or cargo protection in the carrier. A margin is available for such

shielding at 25,000 feet. Decreasing the cruise altitude to 20,000 feet would place the specific weights at about 0.7 the values shown, allowing more leeway for the increased shielding weight. The data indicate, therefore, that the estimated attainable specific powerplant weights are satisfactory for the logistic carrier and the AEW and ASW airplanes. For low speeds, say $M = 0.5$ or less, a turboprop instead of a turbojet would further decrease the estimated specific engine weights because of the higher efficiency of the turboprop powerplant. The fact that the turboprop develops essentially constant horsepower (at constant altitude) results in thrust output decreasing directly as the speed is increased with 4583
the consequent increase in specific weight at the higher speeds. The turboprop would produce appreciably higher thrusts at takeoff and so alleviate the takeoff problems. A single dual engine system would power an airplane of about 400,000 pounds gross weight.

For the on-the-deck SAC bomber, the estimated attainable powerplant specific weights are below the estimated minimum permissible weights, indicating satisfactory performance for this use. For the on-the-deck bomber the powerplant is 0.55 of the gross weight, giving an airplane gross weight of 200,000 pounds to 250,000 pounds.

For the all-supersonic SAC bomber, the specific engine weights shown are all too high. Other calculations not shown in figure 2 indicate that if an airplane L/D as high as 7.4 can be obtained at $M = 1.5$ the specific weight may be considered marginal at 35,000 feet.

At the 1800° F turbine inlet temperature condition shown in figure 3, the specific engine weight is satisfactory for the on-the-deck bomber. For the logistic carrier or the AEW or ASW airplanes, comparison of permissible and attainable specific weights show applicability of the nuclear-powered turbojet. The use of a turboprop instead of a turbojet would improve the situation at flight speeds of $M = 0.5$ or less.

Liquid cycle. - Table V shows the estimated weight breakdown presented by Pratt and Whitney for the liquid cooled (liquid cycle) reactor ANP system. Much of the Pratt and Whitney data considered herein have been received recently directly from Pratt and Whitney and may deviate somewhat from the values presented in the older Pratt and Whitney formal reports. Pratt and Whitney data essentially cover the following three basic systems:

(1) Circulating fuel reactor, where sodium potassium (NaK) cools the reactor;

(2) Solid fuel reactor, where sodium is the reactor coolant with a subsequent Na to NaK heat exchanger;

(3) Solid fuel reactor; where lithium acts as the reactor coolant.

The weights and performance of the solid fuel reactor using sodium as the coolant with a subsequent Na to NaK heat exchanger are about the same as the circulating fuel reactor system.

Data presented for the sodium cooled system is confined to the circulating fuel reactor. Two sets of data are given for the NaK system. The second column of data shown under the NaK system in table V were given by Pratt and Whitney relative to the 125A mission. The difference between the first column of data and the second in the engine (turbomachinery) weights results largely from the fact that the smaller figure is for non-afterburner engines. The difference in the estimated core weights has not been discussed with Pratt and Whitney. The heavier crew shield weight shown in the second column probably results from the fact that this data is for a subsonic airplane with a greater flight time per mission.

The reason for considering the lithium cooled reactor is to provide a means for decreasing the nuclear system weight. Lithium has a lower molecular weight than sodium or sodium-potassium with a consequent higher specific heat. By using lithium-7 and so, presumably, eliminating radioactivity in the coolant, the intermediate wrap-around heat exchanger used with either the liquid fuel NaK system or the solid fuel Na-NaK system is eliminated with a consequent weight saving in the reactor core. It is widely recognized that there are many uncertainties in regard to the use of lithium. These uncertainties need not be discussed here.

Using the figures for estimated attainable powerplant weight and the estimated thrust output for the powerplants results in the curves presented in figure 4. Considering first the NaK cooled reactor data, it is seen that the estimated specific weights are lower than the maximum permissible for the logistic carrier. For these data the shielding is insufficient for either cargo or passenger protection. Inasmuch as an increase in the specific powerplant weight of 50 percent would still result in a satisfactory estimated powerplant weight, it is assumed that adequate shielding for these uses can be added. Substituting a turboprop for a turbojet will increase the powerplant efficiency at the lower airplane speeds and may, therefore, decrease the specific powerplant weight and will increase takeoff thrust as previously mentioned.

For the subsonic logistic, AEW, and ASW airplanes under consideration in which the powerplant is 30 percent of the gross weight of the airplane, the airplane weight is about 650,000 pounds. Considering Pratt and Whitney data, the conclusions drawn on the suitability of the powerplant to the logistic, AEW and ASW airplanes are equally applicable to an airplane of 2/3 this weight or 450,000 pounds.

Turning to the on-the-deck SAC bomber, the estimated attainable powerplant specific weights are satisfactory in regard to the required specific weight at $M = 0.9$, provided the higher values of lift-drag ratio can be achieved.

For the all supersonic high altitude bomber, the specific weights of the NaK cooled reactor powerplant are, as has been stated by Pratt and Whitney, too high. A supersonic bomber at flight speeds of $M = 2.0$ to $M = 2.5$ should preferably fly at 45,000 feet or above, unless wing loadings higher than 150 lb/ft^{-2} are employed.

As a result of the estimated weight savings and the estimated higher permissible average coolant temperature, changing from the NaK or Na-NaK liquid cooled nuclear reactor to the Li cooled reactor appreciably lowers the specific engine weight. At 45,000 feet and $M = 2.0$ where the particular reactor (525MW) and turbomachine studied by Pratt and Whitney are matched, the estimated specific powerplant weight for the Li system is within the limit zone for the 1650° F coolant temperature. For the same powerplant at 50,000 feet and $M = 2.0$, the reactor as estimated by Pratt and Whitney is capable of delivering 29 more megawatts of heat per engine (87.5 MW vs. 58.5 MW) than the air inducted through the engine is capable of absorbing. Considering 50,000 feet altitude and $M = 2.5$ as the design point, a 350 MW nuclear system estimated by Pratt and Whitney at a weight saving of 8,000 to 10,000 pounds over the 525 MW nuclear system might be used. The 50,000 foot curve, *R in figure 4, adjusted for this saving gives an estimated attainable specific powerplant weight that is marginal from $M = 2.0$ to $M = 2.4$. The supersonic airplane considered has a gross weight of the order of 250,000 pounds.

4583

ACKNOWLEDGEMENTS

The cooperation of the General Electric Company and Pratt and Whitney Aircraft Division, the Convair, Fort Worth, Texas Division and Lockheed, Marietta, Georgia Division in making available the data resulting from this current study is appreciated.

National Advisory Committee for Aeronautics
Washington, D. C.
May 17, 1957

APPENDIX

POWERPLANT EFFICIENCY AND SPECIFIC THRUST

4583 The powerplant efficiency of the ANP (designated as over-all engine efficiency) is the ratio of the power expended on the airplane to the power delivered to the turbomachinery by the reactor. The power expended on the airplane is the thrust produced times the airplane velocity. The specific thrust is the ratio of the thrust delivered by the powerplant at the flight condition to the pounds of air per second flowing through the turbomachinery at the flight condition.

Air Cycle

Figure 5 shows the efficiency of the air cycle nuclear powerplant at the turbine inlet temperatures of 1800° and 2000° F. The efficiencies of a nonafterburner chemically fueled turbojet engine are shown for comparison at the same turbine inlet temperatures. The fact that the efficiencies for the nuclear powerplant are lower than those for the chemical powerplant results from the pressure drop through the reactor. This pressure drop represents a decrease in available energy.

The specific thrusts under the same conditions for which the efficiencies are given in figure 5 are presented in figure 6. Part of the decrease in thrust per pound of air for the nuclear powerplant in comparison with the chemical powerplant results from the high pressure ratio used in the air cycle. At $M = 2.5$ (not design condition for General Electric air cycle) this high pressure ratio accounts for about half the decrease in specific thrust. If the turbomachinery can be satisfactorily designed by optimizing the pressure ratio to obtain higher thrust output for the higher Mach numbers, the specific thrust would be increased about 75 percent at $M = 2.5$. This increase would result in a 43 percent decrease in the weight of turbomachinery required or about 12 percent decrease in the specific powerplant weight. The pressure drop through the reactor accounts for most of the remainder of the differences in specific thrust.

Liquid Cycle[1]

The over-all engine efficiencies for the liquid cycle are shown in figure 7. The efficiencies for nonafterburning chemically fueled turbojets operating at a turbine inlet temperature of 1540° F are shown also.

[1]The various temperatures shown for the liquid cycle represent the manufacturer's best estimates based on material temperature limitations in the design.

The fact that the ANP efficiencies with the lithium cooled reactor at 1650° F are close to the values for the chemically fueled powerplant indicates the small pressure loss in the liquid metal-to-air heat exchanger. The lower efficiencies at $M = 1.75$ and above with the 1520° F NaK cooled or the 1450° F Li cooled reactor are accounted for by the lower turbine inlet temperatures.

The specific thrusts under the same operating conditions as used in figure 7 are shown in figure 8. The specific thrust for the Li cooled
reactor with the Li temperature of 1650° F is sufficiently close to the 4583
1540° F chemical curve to indicate small losses in the heat exchanger. At the higher Mach numbers the difference between the two curves is largely attributable to engine design point. Designing the turbomachinery for $M = 2.5$ with the Li cooled reactor would increase the specific thrust about 50 percent and decrease the specific powerplant weight by the order of 15 percent. For the liquid fuel NaK reactor at 1520° F and the Li reactor at 1450° F the decrease in specific thrusts compared to the values for the Li 1650° F reactor is caused largely by the lower turbine inlet temperatures.

4583

AIRPLANE WEIGHT DISTRIBUTION

USE	SAC BOMBER			LOGISTIC CARRIER SUBSONIC AIRPLANES		AEW, ASW
FUEL	CHEMICAL SUPERSONIC OR SUBSONIC AIRPLANE	NUCLEAR SUPERSONIC OR SUBSONIC AIRPLANE	SPLIT MISSION AIRPLANE [1]	CHEM.	NUCL.	SUBSONIC AIRPLANE
W_{af}/W_g	0.20	0.23	0.23	0.27	0.30	CONDITIONS SIMILAR TO LOGISTIC CARRIER
W_{pl}/W_g	.05	.05	.05	.25	.25	
W_f/W_g	.65	.12	.32	.38	.10	
W_e/W_g	.10	.60	.40	.10	.35	
TOTAL	1.00	1.00	1.00	1.00	1.00	

[1] CRUISE AT SUBSONIC SPEEDS ON NUCLEAR POWER ONLY
DASH AT SUPERSONIC SPEEDS ON NUCLEAR POWER PLUS CHEMICAL BURNING

NOTE: FOR NUCLEAR POWERED AIRPLANES LANDING AND TAKEOFF IS MADE ON CHEMICAL FUEL

Table I.

2357

FLIGHT CONDITIONS AND LIFT-DRAG RATIOS

USE	SAC BOMBER						LOGISTIC CARRIER, AEW, ASW SUBSONIC AIRPLANE	
FUEL	CHEMICAL		NUCLEAR		SPLIT MISSION AIRPLANE[1] NUCL.	SPLIT MISSION AIRPLANE[1] CHEM.	CHEMICAL	NUCLEAR
ALT.	65,000	S.L.	45,000	S.L.	25,000	55,000	25,000	25,000
MACH NO.	3.0	0.85	2.5	0.85	0.9	2.75	0.6	0.6
L/D	6.0-7.0	7.0-9.0	5.0-6.0	6.0-8.0	12-15	5.0-6.0	18	18

[1] CRUISE AT SUBSONIC SPEEDS ON NUCLEAR POWER ONLY
DASH AT SUPERSONIC SPEEDS ON NUCLEAR POWER PLUS CHEMICAL BURNING

Table II.

2361

4583

4583

ESTIMATED MAXIMUM PERMISSIBLE SPECIFIC POWER PLANT WEIGHT LB/LB THRUST

USE	SAC BOMBER						LOGISTIC CARRIER, AEW, ASW SUBSONIC AIRPLANE	
FUEL	CHEMICAL		NUCLEAR		SPLIT MISSION AIRPLANE[1] NUCL.	SPLIT MISSION AIRPLANE[1] CHEM.	CHEMICAL	NUCLEAR
W_{eng}/F	.48-.56	.56-.72	2.8-3.3	3.3-4.4	4.2-5.3	1.8-2.1	1.4	5.4
ALTITUDE	65,000	S.L.	45,000	S.L.	25,000	55,000	25,000	25,000
MACH NO.	3.0	0.85	2.5	0.85	0.9	2.75	0.6	0.6

[1] CRUISE AT SUBSONIC SPEEDS ON NUCLEAR POWER ONLY
DASH AT SUPERSONIC SPEEDS ON NUCLEAR POWER PLUS CHEMICAL BURNING

Table III.

2358

WEIGHT BREAKDOWN FOR AIR CYCLE POWER PLANT

ONE DUAL ENGINE SYSTEM

	LBS.	PERCENT TOTAL
1. TURBOMACHINERY (2 ENGINES)	32,150	27.3
2. CORE	12,000	10.3
3. CORE SHIELD AND STRUCTURE	50,850	43.5
4. CREW SHIELD (35,000 LB/2-DUAL ENGINE SYSTEMS)	17,500	14.8
5. MISCELLANEOUS WEIGHTS	5,000	4.1
TOTAL	117,500	100.0
SLS AIR FLOW PER ENGINE, LB SEC^{-1}	400	

Table IV.

2359

4583

4583

WEIGHT BREAKDOWN FOR LIQ. CYCLE SUPERSONIC NUCLEAR POWER PLANTS
NaK AND Li

COOLANT	NaK		Li	
COOLANT TEMPERATURE, °F	1520		1450	1650
MW	380		450	525
NUMBER OF ENGINES	6		6	6
LB AIR/SEC PER ENG. SLS	375		400	400
WEIGHT, LBS				
TURBOMACHINERY	70,100	83,790*	74,790	75,150
LIQUID METAL SYSTEM	29,500	29,500	17,520	19,600
REACTOR CORE	55,900	39,750	20,200	26,200
REACTOR SHIELD	21,080	20,010	14,050	14,290
CREW SHIELD	14,070	18,750	13,170	13,330
MISCELLANEOUS	4,900	4,860	3,270	3,410
TOTAL	195,550	196,660	143,000	151,980
SP. WT. NUCL. SYS., LB/KW	0.278		.161	.146

* VALUES GIVEN TO AD HOC ANP PANEL JAN. 29, 1957, FOR SUBSONIC NUCLEAR POWER PLANT WITH CHEMICAL AB.

2360

Table V.

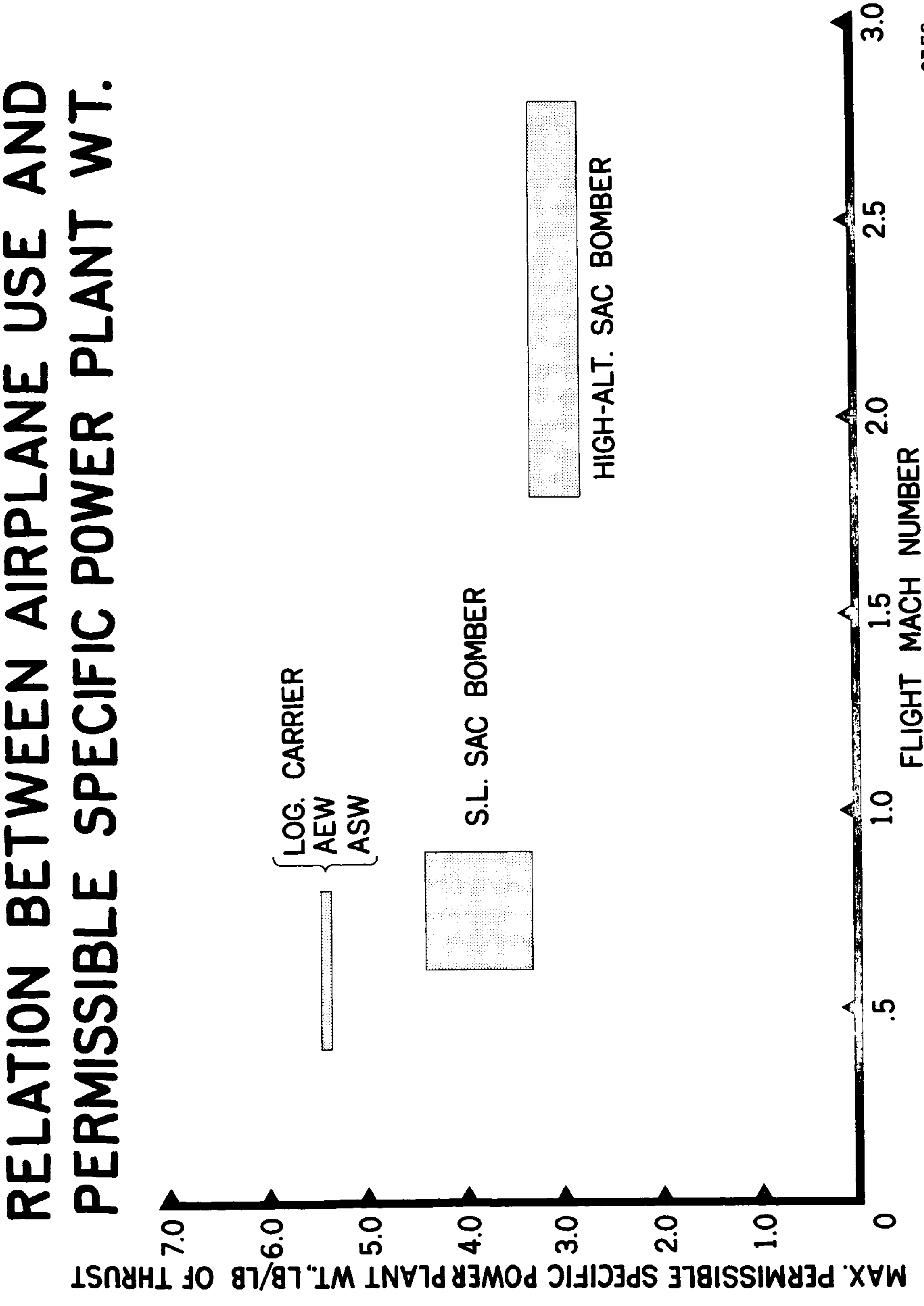


Figure 1.

2356

4583

[redacted]

4583

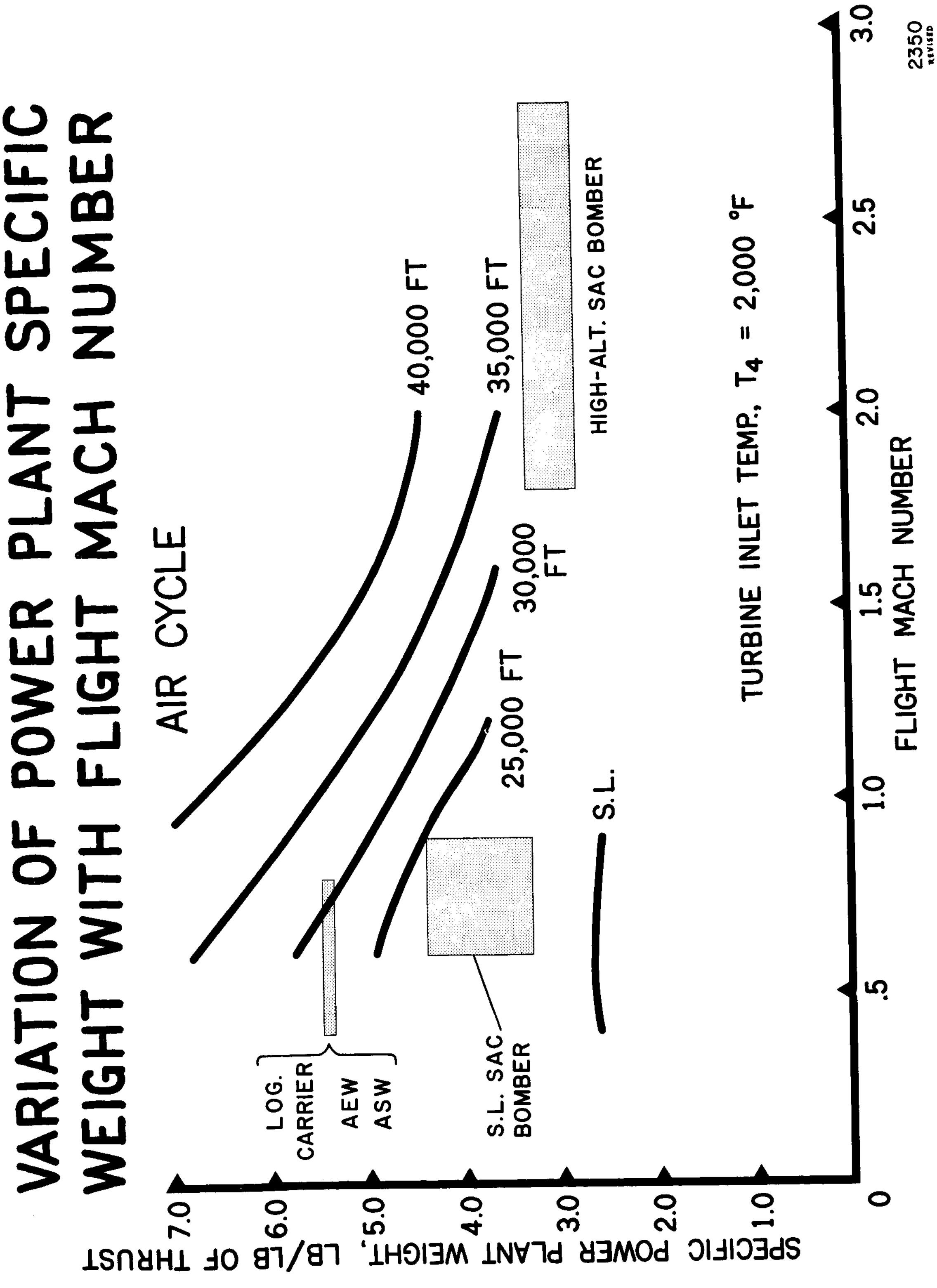
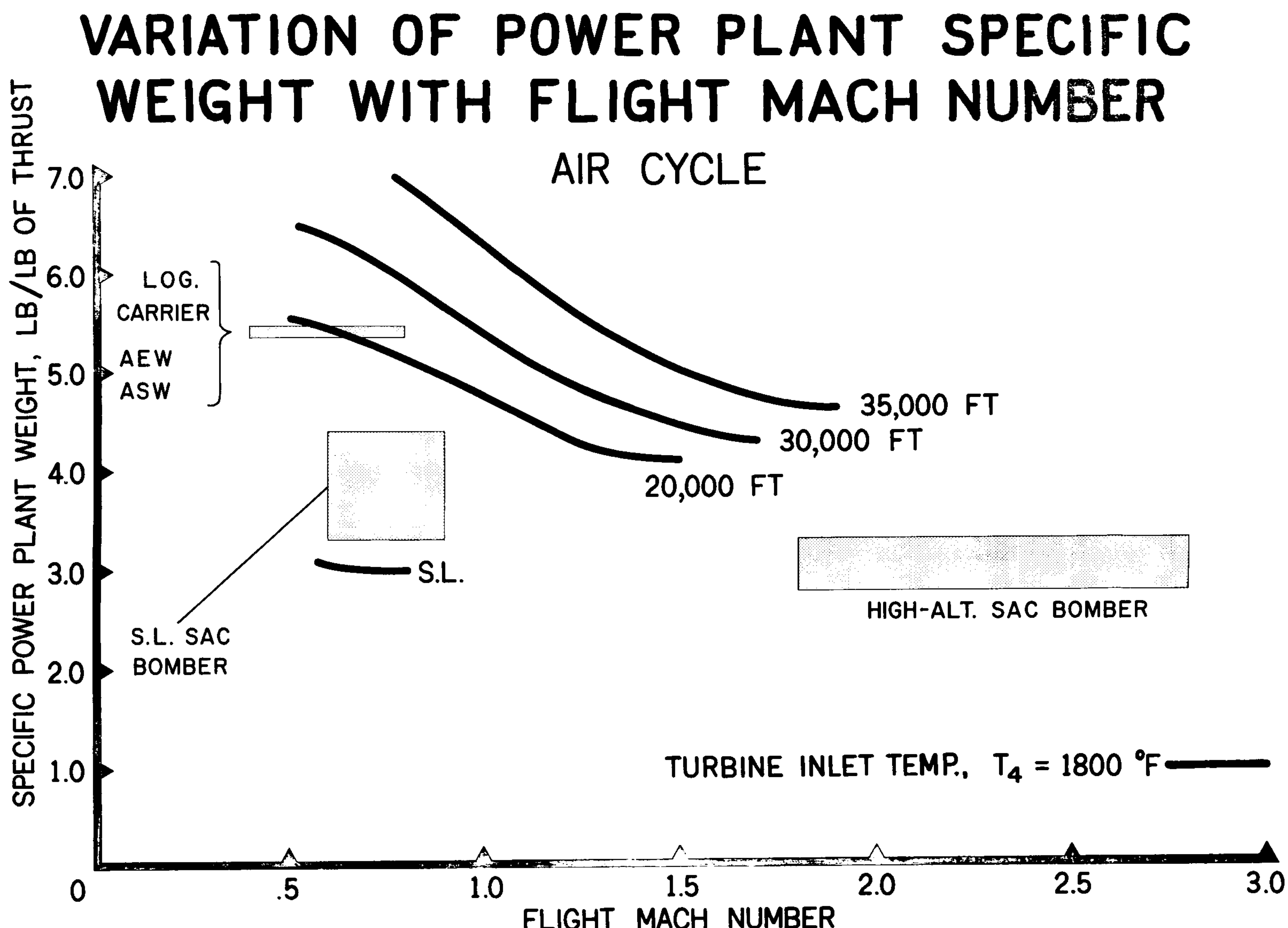


Figure 2.

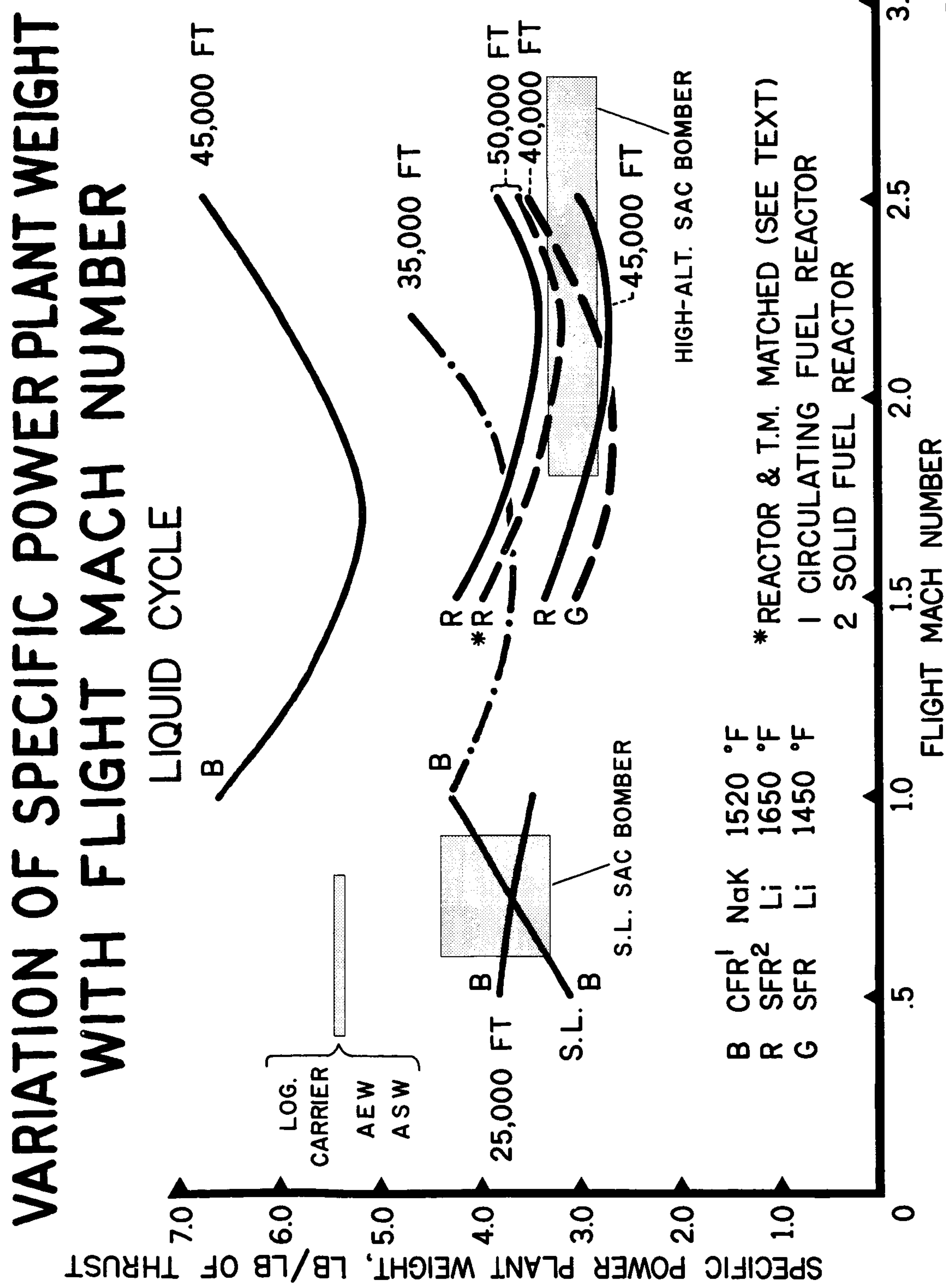


2349

Figure 3.

4583

4583



2351

Figure 4.

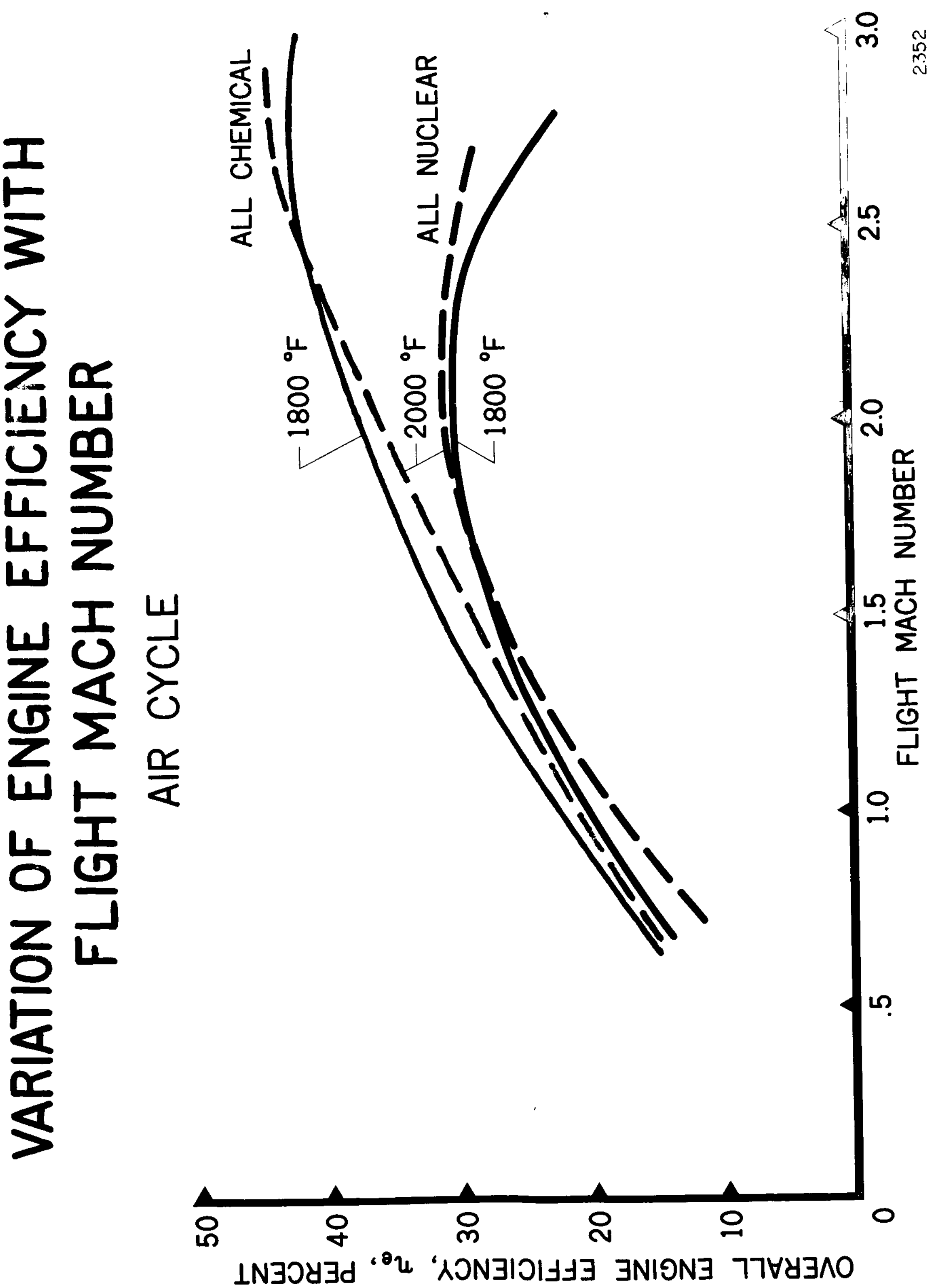


Figure 5.

2352

4583

[redacted]

4583

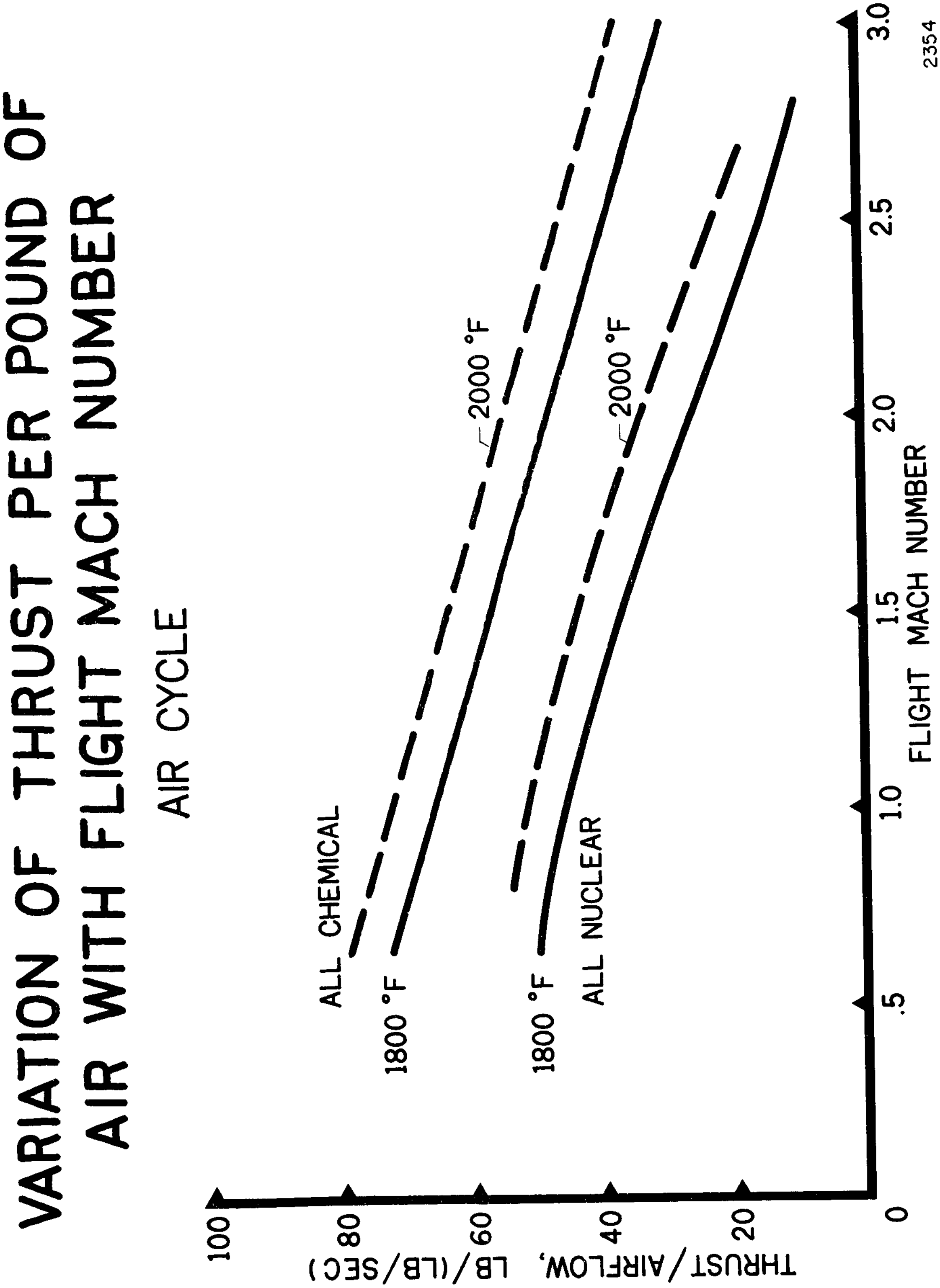
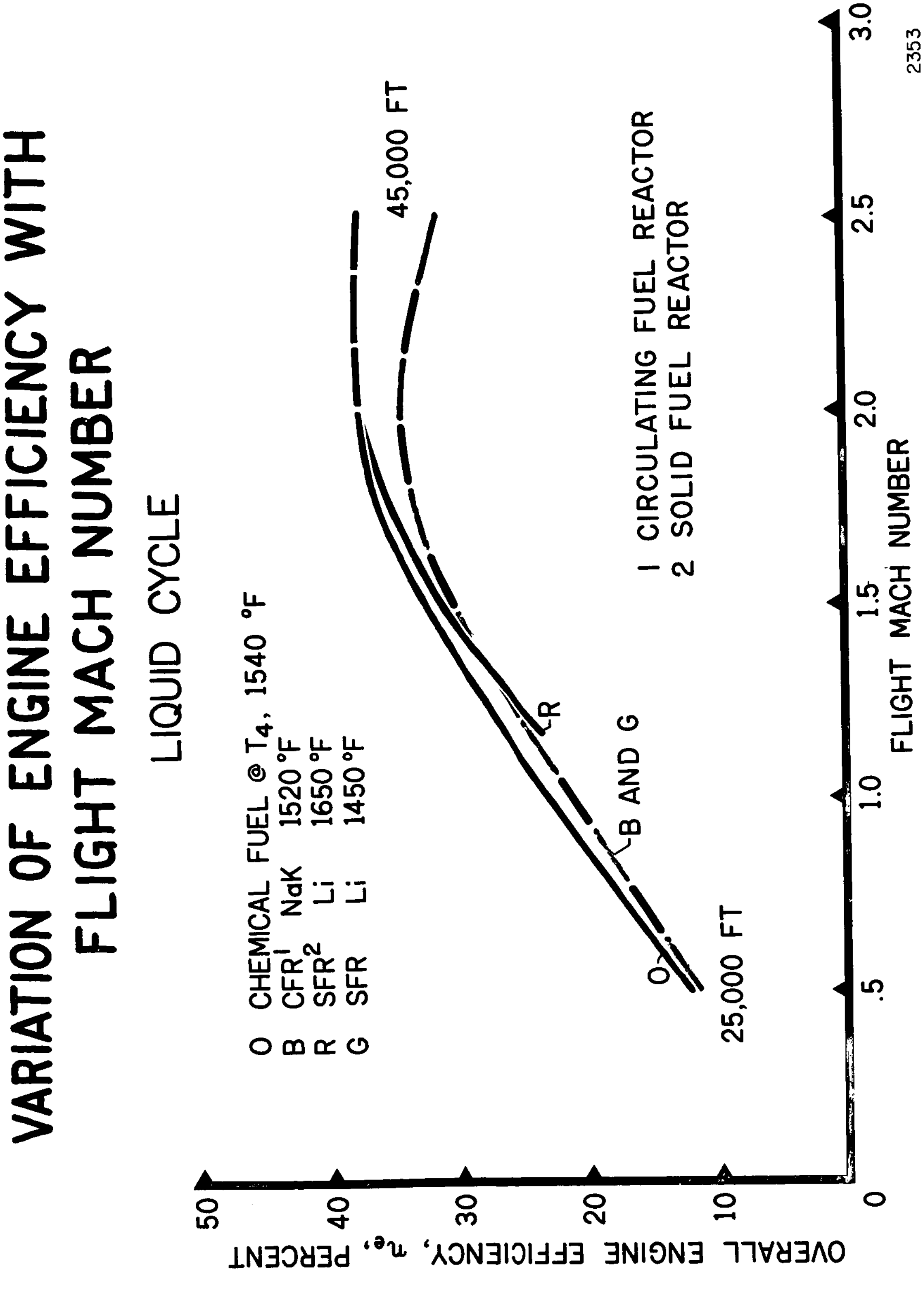


Figure 6.

2354

[redacted]

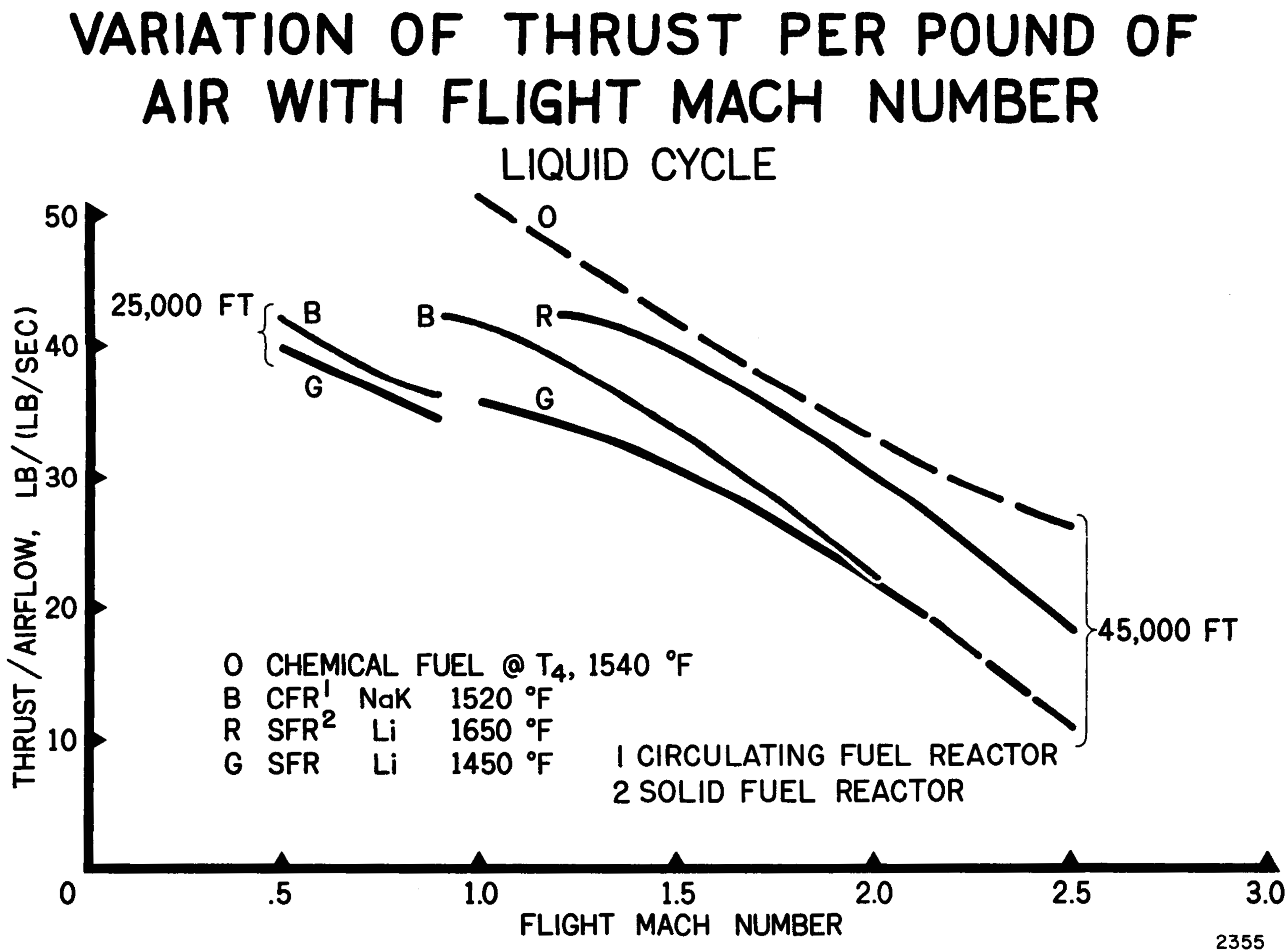


2353

Figure 7.

4583

4583



2355

Figure 8.